Modeling UV-B Effects on Primary Production Throughout the Southern Ocean Using Multi-Sensor Satellite Data

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This study has used a combination of ocean color, backscattered ultraviolet, and passive microwave satellite data to investigate the impact of the springtime Antarctic ozone depletion on the base of the Antarctic marine food web - primary production by phytoplankton. In collaboration with Professor Kevin Arrigo (Department of Geophysics, Stanford University), spectral ultraviolet (UV) radiation fields derived from the satellite data are propagated into the water column where they force physiologically-based numerical models of phytoplankton growth. This large-scale study has been divided into two components: (1) the use of Total Ozone Mapping Spectrometer (TOMS) and Special Sensor Microwave Imager (SSM/I) data in conjunction with radiative transfer theory to derive the surface spectral UV irradiance throughout the Southern Ocean, and (2) the merging of these UV irradiances with the climatology of chlorophyll derived from SeaWiFS data to specify the input data for the physiological models. The first component has been performed by Dr. Lubin, and the second has been performed by Prof. Arrigo.

The numerical modeling experiment has consisted of a control run using TOMS column ozone data for 1979 (before significant springtime ozone depletion occurred over the Southern Ocean), and an experimental run using TOMS data from 1992 (a pronounced ozone hole year) with all other parameters fixed as in 1979. The response in primary production throughout the Southern Ocean was computed for both years, and the difference represents the change in primary production due to a typical springtime ozone depletion event. In the vicinity where detailed field work has been carried out on effects of ozone depletion, our model results show good agreement with the primary production decreases discovered by the 1990 ICECOLORS cruise of Prof. Ray Smith (University of California, Santa Barbara). When integrated over the entire Southern Ocean, the loss of primary production due to springtime ozone depletion is found to be less than 2%. This is due primarily to a lack of intersection between the stratospheric regions containing the lowest column ozone abundances (mostly over the Antarctic continent) with the water column regions containing the largest phytoplankton blooms.

A detailed manuscript describing all stages of this modeling study, with uncertainty analyses, has been prepared by both groups and has been submitted to the Journal of Geophysical Research. These results give us a method for interpreting the springtime ozone depletion of any year in the context of primary production, and a follow-on study is being carried out for all years with additional support from NASA's Atmospheric Chemistry Modeling and Analysis program.